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Description

Method and apparatus for synchronization of a receiver to a transmitter

The invention relates to a method for synchronization of a receiver to a transmitter or to a transmission signal in a digital information transmission system, in particular a mobile radio system, with the method having a step of time synchronization, using at least one filter device which is tuned to a predetermined synchronization code, and also relates to an apparatus for carrying out this method.

It is known for physical channels to be used for transmitting communication information and synchronization data in information transmission systems. The use of these physical channels results firstly in the transmission of the digitized information and secondly in the transmission of a synchronization signal from a transmitting station to a receiving station, in particular without the use of wires, from a first radio station to a second radio station.

In transmission and communications systems which operate on the basis of the DS-CDMA principle (Direct-Sequence Coding Spread Spectrum Principle), a digital information signal with a narrow bandwidth has a radio-frequency bit stream with a wide bandwidth modulated onto it. The latter is produced by a spread-code generator. In the receiver, a code sequence is produced which is identical to the spread-code sequence as used for modulation in the transmitter. In order to ensure that the receiver operates correctly, this receiver-end code sequence must be synchronized to the transmitter. The "despread" information signal is then obtained by demodulation and integration. The most important task

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of synchronization during the signal acquisition phase is to detect the timing and phase of a synchronization signal. In addition,

there are further important synchronization tasks, depending on the method of operation and protocol of the digital information transmission system, including in particular timeslot (slot) synchronization and frame synchronization for a system which is operated taking account of time-division multiplex or TDMA (Time Division Multiple Access) aspects.

In the futuristic UMTS/WCDMA-FDD (Universal Mobile Telecommunication System/Wideband Code Division Multiple Access-Frequency Division Duplex) system, the present Standardization level proposes a three-stage method for synchronization during the acquisition phase. During the initial cell search, the mobile station searches for that base station to which the transmission loss is the lowest. A primary synchronization channel (PSCH) and a secondary synchronization channel (SSCH) are defined for this purpose. During the first step, PSCH is used to obtain time synchronization with the strongest base station. An individual filter, which is tuned to a primary synchronization code c_p which is common to all the base stations is used to determine peaks for each base station within range of the mobile station. The detection of the position of the strongest peak provides the timing for the strongest base station modulo the time slot length. In order to improve the reliability, the output from the tuned filter is accumulated incoherently over a number of timeslots.

The second step in the synchronization process is frame synchronization and code group identification for the base station found in the first step, and this is carried out using SSCH. For this purpose, the received signal is correlated with all the secondary synchronization codes (in this case 17) which are possible in accordance with the system protocol at the positions of a secondary synchronization code c_s. The

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details of this step in the given context are of secondary importance in the same way as those in the third step, which consists of the identification of what is referred to as the scrambling code, which is used by the determined base station. Details of these steps for the system quoted as an example are stated in the system document "ETSI STC SMG2 UMTS-L1 163/98, UTRA/FED Physical Layer Description".

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In consequence, a specific physical channel, namely the PSCH, is provided for time synchronization.

The invention is based on the object of specifying a method of this generic type, in which the received signal energy is made better use of for the time synchronization process, and the measurement time and power consumption for the synchronization process are thus reduced, and of specifying an apparatus for carrying out this method.

With regard to the method aspect, this object is achieved by a method having the features of claim 1, and with regard to its apparatus aspect, the object is achieved by an apparatus having the features of claim 11.

The invention includes the fundamental technical teaching of using at least one additional physical channel in the information transmission system for time synchronization. This improves the utilization of the received signal energy, reduces the time involved, and reduces the power consumption in the receiver. In this case, the expression physical channel means a channel which is characterized by its frequency, a spread code, the time-window location or a space-division multiplex state.

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Time synchronization comprises, in particular, slot or timeslot synchronization and frame or symbol synchronization.

According to one preferred embodiment of the invention, a synchronization channel is used which is intended for a purpose other than that of time synchronization in accordance with the transmission protocol for the information transmission system. In the system outlined above, this is the secondary synchronization channel (SSCH). This results in one implementation option, which requires comparatively little computation complexity, by the code words for the second synchronization channel being obtained by modulation with what are referred to as Hadamard sequences from the code of the primary synchronization channel, or by modulation with some other known code. This is because what is referred to as a "fast Hadamard" transformation can be used for evaluation of the correlation processes in the second synchronization channel for time synchronization purposes.

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However, in principle, it is also possible to use at least one monitoring or data channel in the system for time synchronization as well. This requires the definition of particular channel specifications.

The proposed method includes separate correlation evaluation in the channels used for time synchronization, with the evaluation results subsequently being linked to form a time synchronization indicator. This linking process is incoherent, provided the system protocol is not based on a fixed phase relationship between the channels used for time synchronization. In this context, it is particularly advantageous to provide a fixed and/or defined phase relationship, in particular of ± 90° and, wherever possible, also to use the same antenna for transmitting the two channels using the system protocol, which allows linking by coherent accumulation, and hence better detection than incoherent accumulation.

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~~In addition, the proposed procedure offers the capability of storing intermediate results obtained in the time~~

synchronization step, and using them for further steps, for example for identification of the scrambling code.

The proposed method is used either permanently or as a function of the satisfaction of a predetermined condition, in particular as a function of the capability to evaluate the signals in the respective channels which can in principle be used for time synchronization - for example expressed by the signal amplitude overshooting a threshold value, the bit error rate undershooting a threshold value, or the like.

The apparatus for carrying out the method according to the invention is, in particular, suitable for and intended for use in the mobile station of a mobile radio network. For evaluation purposes, it has a number of correlator stages and a calculation unit for calculating the time synchronization indicator from the outputs from the individual correlator stages using an incoherent or coherent accumulation algorithm chosen depending on the system protocol. The output signals from the correlator stages are linked by linear combination. This results in the following methods for incoherent accumulation in this case:

- combination with equal weights
- square-law combination
- selection method

or coherent accumulation.

Other advantages and useful forms of the solution according to the invention can be found in the dependent claims and in the following description of one preferred embodiment, with reference to the figure.

The figure shows an outline illustration, which is used in the following text both to explain one embodiment of the method and to explain a preferred apparatus for carrying out the method.

The figure shows an apparatus 1 for time synchronization, which can be used as a component of a mobile station (not illustrated overall) operating in accordance with the UMTS/WCDM-FDD Standard. A received signal x(k) is subjected to synchronization evaluation in a primary synchronization channel PSCH and in a secondary synchronization channel SSCH. A correlator stage 3 is provided in the primary synchronization channel PSCH.

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The correlation stage 3 uses the following relationship for calculation:

$$y_p(\kappa) = \frac{1}{N} \cdot \sum_{k=1..2560} x^*(k+\kappa) \cdot c_p(k) \qquad (1)$$

where:

N is the normalization constant (in this case 2560)

$x^*(k)$ is the complex-conjugate input signal

c_p is the primary synchronization code in accordance with the UMTS/WCDMA-FDD specification 256 chips (in this case 2560 chips with $c_p = 0$ outside the 256 specified chips)

of the correlation function (correlation) for the primary synchronization channel PSCH.

In the secondary synchronization channel SSCH, the input signal is supplied (in accordance with the protocol definitions worked out at the time of the application) to 17 correlators, which are denoted overall in the figure by the reference number 5. These use the relationship

$$y_s^i(\kappa) = \frac{1}{N} \cdot \sum_{k=1..2560} x^*(k+\kappa) \cdot c_s^i(k) \qquad (2),$$

to define the correlations $y_s^1(\kappa) \ \ldots \ y_s^{17}(\kappa)$,

with the symbols N and $x^*(k)$ being explained in the same way as above and in which case, in addition,

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c_s^i is one of 17 secondary synchronization codes in accordance with the UMTS/WCDMA-FDD specification 256 chips (in this case 2560 chips with $c_s^i = 0$ outside the 256 specified chips), i = 1...17 depending on the synchronization code.

The output signals from the correlators 3 and 5 are supplied to an evaluation and calculation unit 9, which calculates the overall correlation z(k) as the time synchronization indicator either coherently using the relationship

$$z(\kappa) = \max_i \left| y_p(\kappa) + k(y_s^i(\kappa)) \right|^2 \qquad (3)$$

or incoherently using the relationship

$$z(\kappa) = \left| y_p(\kappa) \right|^2 + k \left| \max_i (y_s^i(\kappa)) \right|^2 \qquad (4),$$

or

$$z(\kappa) = \left| y_p(\kappa) \right| + k \left| \max_i (y_s^i(\kappa)) \right| \qquad (5),$$

k being a real constant.

In a downstream evaluation stage 9, this is subjected to accumulation modulo the timeslot length, and then to

maximum detection in a maximum detector 11, whose output produces the time synchronization to the "best" base station in a mobile radio system.

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With regard to the calculation process, the correlation evaluation in the secondary synchronization channel SSCH in the UMTS/WCDMA-FDD system explained by way of example is particularly simple, if the code words for the secondary synchronization channel are formed from the code for the primary synchronization channel PSCH or from some other known code by modulation with what are referred to as Hadamard sequences, as proposed in the Conference Proceedings, from Ericsson, ETSI SMG2 UMTS L1 Export Group, Meeting # 6, Helsinki, FI, September 8-11, 1998. In this case, a fast Hadamard transformation is used, which is likewise described as such in the cited document.

The implementation of the invention is not restricted to this example but - in a form matched appropriately to the respective system protocol - is also feasible in other digital information transmission systems in which time synchronization of a received signal is relevant.